AUG 5 1924

Volume 10 June, 1924 *Number 6*

Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

The Status of Asphalt

Consumption and Dilution of Automobile Engine Oils

PUBLISHED MONTHLY BY
THE TEXAS COMPANY, U.S.A.
TEXACO PETROLEUM PRODUCTS

Since Father Noah—

Since Father Noah calked his Ark with Bitumen the engineering and industrial world has developed many uses for Asphalt.

Some of these are discussed in the pages of this issue.

But even in the face of the increasingly diversified application of this product, Road Building and Road Preservation take over half of the world's output of asphalt; so then it is entirely fitting that an asphalt producer be judged by his record in that field.

Here then is a part of the Texaco record:

> More than 750 cities in the United States pave their streets with Texaco Asphalt.
>
> 25 State Capitals pave their streets with Texaco.
>
> United States Government roads, cross-continent routes, such as the Lincoln Highway, State Highways systems, and county and town roads are paved with hundreds of miles of Texaco Asphalt.
>
> England, France, Australia, Brazil, South Africa—all these and other countries know the value of Texaco Asphalt by actual use.

With such a wide field it will be seen that Texaco Asphalt is meeting every condition of service, traffic and climate.

It is also patent that the Texaco Highway Engineers who have cooperated in this construction have on hand a vast fund of practical experience.

This is an invitation to call on them any time you require assistance on problems relating to the construction or restoration of roads or streets.

For those who are interested in a closer study of the subject, we have a series of brief but thorough booklets. Send for those you want.

Texaco Sheet Asphalt
Texaco Asphaltic Concrete
Texaco Asphalt Macadam
Texaco Paving Filler
Texaco Road Oil and Surfacing Material
Texaco Cold Patch

THE TEXAS COMPANY, U. S. A.

Asphalt Sales Department

Dept. H, 17 Battery Place, New York City

TEXACO

LUBRICATION

A Technical Publication Devoted to the Selection and Use of Lubricants

Published Monthly by

The Texas Company, 17 Battery Place, New York City

Copyright 1924, by The Texas Company

Vol. X June, 1924 No. 6

Change of Address: In reporting change of address kindly give both old and new addresses.

"While the contents of LUBRICATION are copyrighted, other publications will be granted permission to reprint on request, provided article is quoted exactly and credit given to THE TEXAS COMPANY."

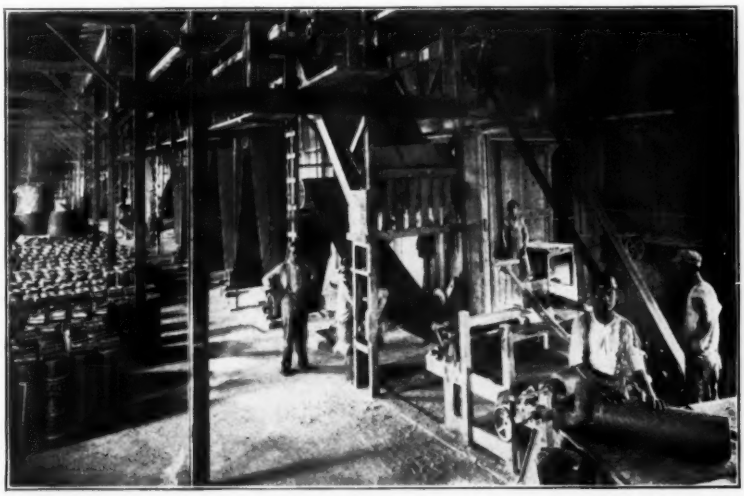

Fig. 1.—Interior view of an asphalt roofing plant, showing the general process of rolling involved

The Status of Asphalt

PETROLEUM asphalt is practically 100% soluble in carbon disulphide, whereas so-called lake or native asphalt will show from 65 to 95% solubility. This means little or nothing to the average layman. On the other hand the fact that petroleum asphalt is obtainable at about half the price of native asphalt is of vital concern to us all. When we look further and note that in highway construction the cost of various grades of asphalt per square yard of pavement is approximately:

Petroleum (Pure Asphalt)	19.0 cents
Bermudez (Native Asphalt Cement)	31.0 cents
Trinidad (Native Asphalt Cement)	50.0 cents

we are indeed interested in asphalt and its usage.

To many, the query "What is asphalt?" has often arisen. An extensive technical definition will be quoted later. For the present a simplified statement will suffice to the effect that asphalt is a black, sticky, waterproof material of varying degrees of hardness, the original source of which is petroleum. In other words, asphalt is a semi-solid or solid substance derived from certain grades of petroleum or crude oil by partial distillation or evaporation of the lighter components. Whether it be produced or refined by natural evaporation in its original deposit, or by mechanical treatment in the oil refinery, the ultimate product is essentially similar, with the exception of the impurities that may be present.

In practically every native asphalt except pure Gilsonite there is a certain content of mineral and vegetable foreign matter. Some of this matter is removed during the subsequent mechanical process of refinement after the crude asphalt has been dug from its deposit. Water, wood and other vegetable growths can be removed by dehydration and skimming. A certain amount of entrained mineral matter and sometimes particles of vegetable matter can not, however, be removed by artificial refinement. For this reason native asphalt is seldom "pure" asphalt, even after refinement.

Petroleum asphalt, on the other hand, is a practically pure bitumen after the distillation of the oils in which the asphalt is contained. The solid mineral content of many grades of crude petroleum is comparatively negligible. Where suspended mineral matter does occur it is feasible to remove the greater part by suitable settling and sedimentation.

The relation between petroleum and native asphalt, as regarding their comparative value to industry, is often overlooked. Native asphalt is not suitable for industrial uses in its original or mined form. In other words, it is "impure." It must, therefore, first be purified or refined, as stated above, by heating and agitation in order to remove water by dehydration, and solid impurities as far as possible by skimming or sedimentation. The resultant asphalt is then too hard for paving purposes or certain commercial uses; therefore it must be fluxed or reduced to the proper consistency by the addition of a residual petroleum product known as flux oil, which may or may not contain asphalt. Often as high as 60% of this flux must be used in order to obtain a final product of the desired consistency and melting point. In view of the above it can be appreciated that native asphalts as used are in reality artificial in nature; far more so in fact than oil asphalts which can be reduced directly to the requisite consistencies from crude petroleum by the process of distillation.

ECONOMIC VALUE

The economic value of asphalt is essentially governed by its purity. Some grades of native asphalt contain as high as 36.0% of mineral matter. Petroleum asphalts on the other hand usually run well under 0.5% of foreign matter. At $25.00 a ton for the former we are therefore paying at this rate for 36.0% of mineral matter which could ordinarily be obtained (as limestone filler) for about $6.00 per ton. But filler is not always necessary; therefore in many cases we would be paying for an element that serves no useful purpose, and in certain cases may even be objectionable. For paving purposes as well as manufacturing, petroleum asphalt is more suitable than native asphalt, due to its purity, i.e., freedom from foreign matter, and is specified by many engineers and manufacturers wherever possible.

The comparative prices of the more common asphalts in use today indicate the petroleum product to be considerably lower than that of native asphalts. This price difference is not caused by any recognized inferiority of petroleum asphalt. Rather, in the production of this type of asphalt there is keen price competition commensurate with actual cost.

DETERMINATION OF QUALITY

Mention has been made of relative solubility of asphalt in carbon disulphide. Just what does this mean, and why should it interest us? We must answer from a chemical viewpoint.

Chemistry has proven that pure asphalt is completely soluble in carbon disulphide; most impurities are not. As a result, an analysis of any commercial asphalt which shows the percentage solubility in carbon disulphide will indicate to a large extent the purity of the product.

Fig. 2.—The construction of an asphaltic concrete pavement, showing the method of spreading, raking and rolling to form a smooth surface.

The following table of relative solubilities of the usual grades of asphalt which are employed for paving highways, and for other purposes, is very enlightening:

Petroleum (Pure Asphalt)
99.8% Soluble
Bermudez (Native Asphalt Cement)
92.0–95.0% Soluble
Trinidad (Native Asphalt Cement)
65.0–75.0% Soluble

As a result of these differences in solubility, slightly more Bermudez and considerably more Trinidad asphalt will be required to serve a given purpose, if used instead of petroleum asphalt.

The term "asphalt" has been so variously applied in the past to many different sub-

stances that it is well to once and for all correct any possible future misunderstanding by quoting the accepted definition of the American Society for Testing Materials, viz:

Asphalts: "Solid or semi-solid native bitumens, semi-solid or solid bitumens obtained by refining petroleum, or solid or semi-solid bitumens which are combinations of the bitumens mentioned, with petroleums or derivatives thereof, which melt upon the application of heat and which consist of a mixture of hydrocarbons and their derivatives of complex structure, largely cyclic and bridge compounds."

Now contrast the above with the opinion of certain foreign engineers which interpret the term "asphalt" to embrace practically everything that is black, solid or semi-solid, and which melts or liquefies on the application of heat; or the idea of certain interested authorities who would desire to restrict this term to lake asphalts only or certain types of asphalt rock.

It is perfectly evident how far fetched these misconceived ideas are, if we assume the definition of the American Society for Testing Materials as standard. Here the term "asphalt" is essentially limited to solid or semi-solid hydrocarbons occurring in nature as such, either in solid or semi-solid state or as a component part of crude petroleum, and obtained therefrom by the removal of the accompanying oil.

In connection with this question of what the term "asphalt" is really intended to cover, the composition of this substance is of interest. The American Society for Testing Materials makes certain statements as to "hydro-carbons of complex structure" and speaks of "cyclic and bridge compounds." But in reality these are obscure remarks and mean little to many of us. A practical determination will be perhaps more enlightening, a determination which will in fact make clear the very definite relation that oil bears to asphalt, and dispel the idea that native asphalt has any advantage over petroleum asphalt by reason of its seeming original freedom from petroleum oils. For example, if asphalt is digested with a light gravity petroleum naphtha we can effect a separation of two substances; one a blackish, brittle and relatively hard solid, the other an oil. The percentages of these compounds that will result will depend upon the consistency of the original asphalt. A comparatively hard, high melting point product will be correspondingly high in this black solid and low in oil. As the melting point decreases the oil content will increase. Bermudez asphalt from Venezuela has approximately a 70% oil content with 30% of solid matter. Trinidad asphalt on the other hand shows about 65% oil with 35% of black solid. Another grade of native asphalt known as Gilsonite shows about 47% of oil under this test.

The above treatment of asphalt with light naphtha indicates that the complex nature of the hydro-carbon constituents is of little or no concern to us. The rough separation of these, however, into two essential parts of decidedly different properties is exceedingly important. It is indicative of the part that oil bears to asphalt in general, and practically proves that were it not for this oil content, asphalt would not possess the properties which render it so valuable to our industrial and daily life. This does not agree with the claims of many natural asphalt adherents that petroleum asphalt is inferior simply because it is the result of distillation of crude, asphaltic base oil.

In view of the above indication that petroleum oil is a necessary adjunct to asphalt, if it is to be of industrial value, the reference to petroleum asphalt alone as "manufactured" or "oil" asphalt seems to be out of place. Asphalt must contain petroleum oil in the form of so-called complex hydrocarbons, if it is to be of any value commercially. Every asphalt, even to the hard, brittle product known as Gilsonite, is an "oil asphalt" if the term "oil" is intended to describe a constituent of the commercial product.

Fig. 3.—Applying asphalt binder to surface course of a penetration Macadam road.

REFINING

In regard to the refining of asphalt we will be informed by the adherents of the native product that the refining process of nature is relatively faultless. It would seem to be logi-

cal, however, to look askance upon such statements. In the process of distillation, human engineering skill with the multitude of means for determining the properties of the products, would naturally be expected to give more dependable results than the reactions of nature which occur relatively by accident. We have little knowledge as to just how or at what temperatures the petroleum constituents are removed from an asphaltic base crude by nature, resulting in asphalt deposits. It is generally regarded that the process of distillation is involved, however, in some manner or other, whereby the lighter constituents are removed by vaporization. At all events it is certain that nature has no definite requirements in view when crude petroleum is so treated. Therefore, it is perfectly logical to consider that these products of nature have not been formed under as uniform control as the grades of pure asphalt that are produced by the engineering ingenuity of man.

Again, there is another advantage to be considered in regard to asphalts that occur in nature in combination with petroleum oils. The oily constituent is already present in such products. Therefore, by accurately controlling the rate of its removal by distillation, finished asphalt can be produced of any desired characteristics. Is this not a more dependable means, therefore, of developing, let us say, an asphalt for pavement construction, than taking a crude asphalt from which nature has removed an excess of this oily constituent, and attempting to bring it back to the proper consistency, etc., by the addition of a certain amount of petroleum oil or flux?

USES OF ASPHALT

Asphalt occupies perhaps as varied a position in modern industry as any product we have to deal with. From the asphalt highway to our composition floor coverings and electrical insulation it enters into our daily life. Approximately 85% of the asphalt production goes to the paving and roofing industries. As an excellent waterproof adhesive it is entering more and more into other work.

Paving

In the paving industry asphalt is not only used as a component part of certain types of asphalt pavements themselves but as a joint filler for brick, concrete, wood block and stone block pavements. In general it constitutes from 5 to 15% of the weight of the pavements in which it is used as a cement. It also is extensively used for forming a protective surface on non-bituminous types of pavements. On certain asphalt pavements unevenness of surface often to the extent of considerable depressions and bumps will occur. Many motorists will regard these as the fault of the asphalt used, and decry pavements of this type. In reality whatever the surfacing material it is only as good as the roadbed or foundation upon which it is laid. Therefore if a careless or incompetent engineer lays an unsuitable foundation, or if traffic has increased above the capacity of the pavement, no surface will withstand the combined effects of wear and sub-surface settlement. On a concrete highway, due to brittleness, perhaps the surface might chip and an actual hole would appear. Where an asphalt surface is used its flexibility will permit the pavement to conform to the irregularities which may develop in the foundation.

In highway construction asphalt is used hot, in order to facilitate penetration and handling. In general, there are three distinct types of asphalt pavement, viz.:

a. Asphalt macadam, wherein the asphalt is poured hot over a course of broken stone similar to that used in waterbound macadam construction. This process is known as the penetration method, by virtue of the fact that the asphalt penetrates through the road-bed, coats the stone and effectively binds the aggregate together. A seal coat of hot asphalt and crushed stone completes the pavement. In many cases this type of construction may be used as a base for a sheet asphalt or asphaltic concrete surface.

Fig. 4.—Asphalt serves also as an excellent flooring preservative. In this case asphalt mastic is shown in process of application to the floor or deck of a railroad car float.

b. Asphalt concrete, wherein the asphalt cement and certain aggregates such as crushed or broken stone, slag, sand or pulverized mineral matter are intimately mixed together, and either spread evenly over the road-bed and rolled, or compressed into blocks and laid in courses as in brick or stone block construction. This type of mixture is coming into use as a base for sheet asphalt top, and is known as "black base."

c. Sheet asphalt is a mixture of asphalt cement with specially graded sand, limestone,

and other uniformly pulverized mineral filler. Sheet asphalts are extensively used for re-surfacing worn pavements. Sheet asphalt is the type of pavement most commonly used for dense traffic and on high class city streets which are not subjected to the action of heavy, slow-moving vehicles.

Roofing

Asphalt plays a prominent part in the roofing industry due to the attractive grades of shingles and roofing, etc., that have been developed. In the preparation of such material various thicknesses of felt are impregnated and saturated with heated asphalt by soaking in a saturation tank and passing through a series of steam heated rolls. Thereby the air is displaced by the liquid asphalt, and at the same time any excess of the latter is removed. The treated felt is then cooled and wound into rolls. In the manufacture of shingles and prepared roofing this asphalt saturated felt is coated and rolled with harder asphalt and variously colored by powdering with mineral matter. During rolling, the coating is fed from an overhead reservoir, the rolls serving as distributors. Final treatment constitutes cooling and winding, if prepared roofing is desired, or cutting, if shingles are to be made.

Water-proofing

A use for asphalt very similar to that for roofing is the water-proofing and damp-proofing of masonry structures, both above and below ground level. For damp-proofing, liquid products are usually employed and for water-proofing, asphalt products which liquify under the application of heat.

Two forms of water-proofing in which asphalt is exclusively used are the membrane and mastic methods. They may be used separately or in combination. In the first method, the membrane is composed of alternate layers of asphalt and asphalt-saturated fabric. In the mastic method, a mixture of hot asphalt and sand is applied as a trowel coat in thickness up to an inch and one-half. Customarily, a water-proof layer is protected from mechanical failure by a facing of masonry.

Electrical Insulation

By virtue of its high electrical resistance and its ability to withstand acids, alkalis, moisture and effects of the weather, asphalt has been developed into a valuable adjunct in the manufacture of electrical equipment covering. For such service, according to the specific requirements, asphalt is often variously compounded with resins, fixed oils, rubber, and a certain amount of sulphur, and applied to electric wiring, coils, etc. This compound is also used as an insulator and seal in conduit and cable work, sometimes incorporated with other materials. In the preparation of wire insulation the fabric may either be impregnated with the asphaltic mixture, or both saturated and coated, according to the service that is to be required. The method of saturating wire covering is practically the same as that employed in the preparation of asphalt roofing. Where used on wire for exposed conditions, usually a harder grade of asphalt is employed in the surfacing compound.

Paints and Varnishes

Both petroleum asphalt and certain natural asphalts such as Gilsonite have proven to be very suitable as a bituminous basis for water-proof paints and varnishes. In paints and varnishes of this nature the base is mixed with from 30 to 50% of a volatile solvent, and if desired, certain vegetable drying oils and pigments.

However the compound is prepared, the consistency of the asphalt must be reduced sufficiently to enable easy brushing of the final product. Upon application the solvent evaporates spontaneously, the body of the paint drying accordingly. The addition of vegetable oils causes a toughening of the coating. They are usually made by suitable heating of the base and gradual addition of the solvent and other ingredients. Throughout the process the batch is kept in constant motion by agitation. When it is desired to increase weather resisting properties, or to produce higher colors when pigments are to be used, asphalt paints may oftentimes be mixed cold with certain proportions of varnish.

Asphalt paints serve a variety of uses. They may be used for protection of surfaces exposed to fumes, moisture, acids and alkalis. They also serve for the recoating of certain asphaltic roofing materials. Roof paints usually contain the highest proportion of asphalt, from 50 to 70% of this base being used. Masonry paints contain from 30 to 50% of asphalt.

Floor Coverings

Another extensive use of asphalt is found in the manufacture of floor coverings. Due to their comparative cheapness, superior durability and highly waterproof characteristics, such products are more adaptable to our modern requirements than other grades of prepared floor coverings. The process of manufacture embodies the impregnation of rag felt with a relatively hard grade of asphalt, much in the same manner as roofing is prepared. After suitable drying and seasoning the fabric is treated with a priming coat, again dried, and

then, if necessary, printed with suitable designs according to trade requirements. After a final drying period in a steam heated dry-room it is ready for the market.

Insulating and sheathing papers, mastics for walks and floors, wall boards, electrical insulating tape, wood and steel pipe coatings, briquetting cements (for pulverized coals, etc.) waterproof membranous materials, and rubber goods are other products wherein asphalt is an important and very necessary ingredient.

CONCLUSION

Although we have touched but briefly upon the matter of asphalt, attempt has been made throughout to bring out forcibly the extremely valuable nature of this product of petroleum. If we have been able to clarify its status as to source and economic value, and give a sufficient impression of the part it plays in our daily life, the purpose of this discussion will have been realized.

Consumption and Dilution of Automobile Engine Oils

THE average motorist little appreciates the extent to which the oil industry is endeavoring to increase the operating efficiency of his automobile and reduce his running expense, through intensive research. In fact it is even unfortunately the opinion of many of us that the ultimate object of the industry is solely to outdo itself in regard to the matter of gasoline and lubricating oil sales. In reality, however, research and the development of satisfactory products are quite as important to the oil man as the volume of sales which accrue, for the latter can often be measured in a dollars and cents ratio according to the extent to which new products are developed and the characteristics of the accepted ones now on the market are improved.

Research is not merely a matter of cut and try experimentation. It is rather a study of variable conditions, for it is this which often leads chiefly to valuable conclusions. To make such a study effectively, each variable must be considered separately, all other factors being maintained as constant as possible. A paper read before the recent meeting of the Society of Automotive Engineers* is indicative of this fact. This paper covers a series of experiments having to do with the consumption and dilution of automobile engine oils. It will be noted that it was relatively impossible to obtain check results on many of the preliminary road tests carried out, due to the very reason that it was impossible to control the several variables involved. This is no reason for regarding these tests as without value, however, inasmuch as after all the ultimate efficiency which will be obtained from any motor car will depend upon the features of operation, the mechanical condition of the engine and the ability of the operator.

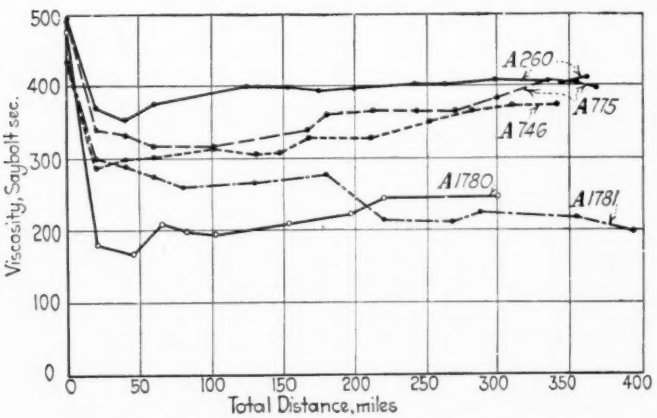

Fig. 1.—Daily viscosity readings on five trucks, showing a great variation in the extent of dilution.

The purpose of this study was to determine, if possible, further information in regard to the consumption and dilution of motor oils, in addition to that developed by the Bureau of Standards on fuels about a year ago. In the case of the work done by the Bureau, the data was the result of road tests. The above investigation extended the program to cover both road and laboratory tests, using a dynamometer installation for this purpose after sufficient data had been gathered from the road tests. The pre-

*A paper on "Consumption and Dilution of Engine Oil," read by Neil MacCoull, Automotive Engineer, The Texas Company. The data brought out in this paper was developed in connection with the experimental work being conducted at the Mechanical Engineering Laboratory of The Texas Company, on factors controlling correct automotive engine performance.

liminary work therefore involved road tests on a number of 7½ ton trucks during their regular course of daily operation. At the start of these tests precaution was taken to have all of the trucks in as nearly identical mechanical condition as possible, and to standardize upon the operators' abilities within the limits available.

Figure 1 brings out certain very interesting data as gathered from these tests. Of primary importance is the great difference in dilution as shown by this figure, typical of results of daily tests of the viscosity of the oil in the crankcase of each truck. Over the period of these tests, the fuel and lubricating oil were the same in each instance. The gasoline consumption varied from 2.2 to 3.0 miles per gallon, but in no consistent way to suggest that it might have been a cause for the different dilutions. The only other evidence to explain this difference in the behavior of these trucks was their rate of lubricating oil consumption, which varied from 79 miles per gallon to 450, or a variation of 500%.

The shape of the curves shown in Figure 1 indicates that there is not an unlimited progressive loss of viscosity but that after a moderate length of time, a condition of equilibrium is reached, after which there may be no further dilution. Several instances are shown where the elements which control this point of equilibrium have apparently changed during the test and the oil viscosity has actually risen. With such curves before one, it is indeed difficult to tell an automobilist how many miles he can drive his car before he must change his oil, if dilution is given as the sole reason for the change.

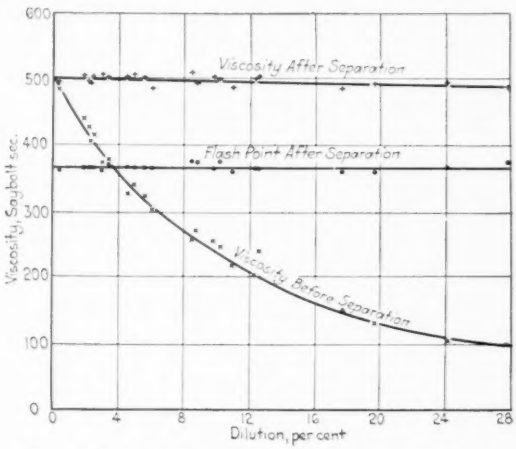

Fig. 2.—Curves showing relationship between viscosity of used oil and percent. dilution. This holds true only for the particular oil used in these tests.

In the determination of this data, viscosity has been used as a measure of dilution since it is more practical than to attempt to determine the actual percentage of dilution by means of distillation in each instance. In order to convert viscosity readings to their equivalent percentage of dilution, it was necessary to develop a relationship between viscosity and the extent of dilution of the oil. This was done by

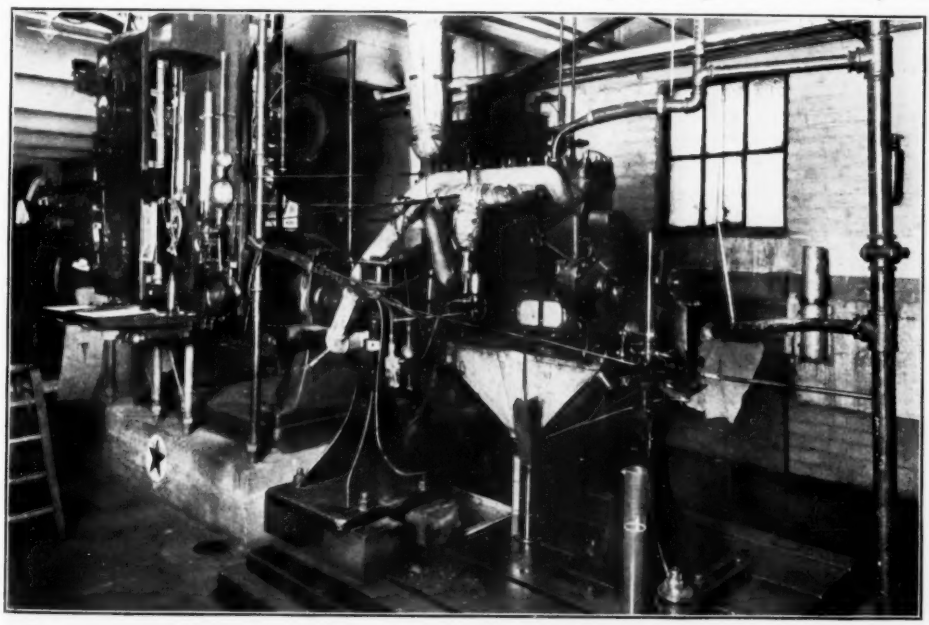

Fig. 3.—General view of the experimental equipment used in this work. Note the engine in the foreground, and the location of the oil pump at the right, where it is driven by change gears; also the shape of the oil pan and the glass sump graduate beneath it.

distilling under constant vacuum to a predetermined end point a large number of residual oils taken from trucks in actual service. In Figure 2 is shown the curve in question. It is based upon the results from 22 such distillations, the percent. found by distillation being plotted against the viscosity before distillation. The diluent which separated from all the samples of used oil was found to be approximately uniform in consistency, regardless of the grade of fuel used.

All this road data proved to be suggestive, and a basis for the carrying on of an accurate series of dynamometer experiments to explain if possible the effects of the many temperature and mechanical variables on the rate of oil consumption and dilution when only one factor was allowed to vary at a time.

DESCRIPTION OF THE DYNAMOMETER APPARATUS

The engine used for the laboratory experiments was a Waukesha, Model DU-8 of 4½" bore and 6½" stroke, with cast iron pistons, and a lubrication system of the circulating full pressure type serving the three main crank-shaft bearings and the connection rod bearings by means of passages drilled in the crank-shaft. As is customary, a spring loaded pressure regulating valve was originally provided in the oil lines, the function of which was to hold the oil

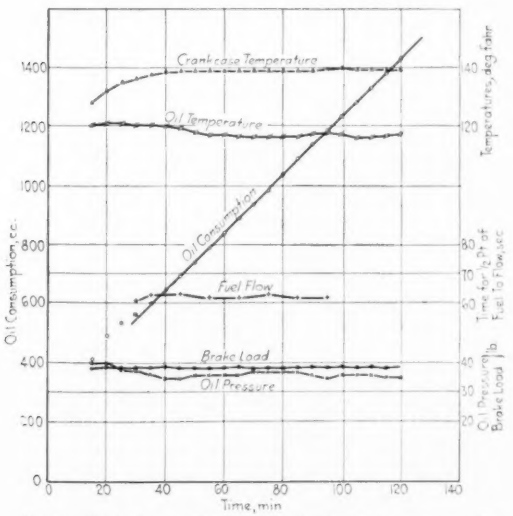

Fig. 4.—Typical curve of test results showing the several operating variables which were observed. The regularity of the oil consumption readings after the first half hour should be noticed.

pressure automatically at about 8 pounds per square inch. The cylinders were lubricated in the usual way by oil thrown from the connection rod bearings. The engine was in fairly good mechanical condition, but by no means new. It had been run for a long period before these tests, and the cylinders were worn to a taper of about 10 thousandths of an inch, though they were hardly 2 thousandths out of round. The engine thus represented more nearly an average engine as found in service, than a job just out of the factory.

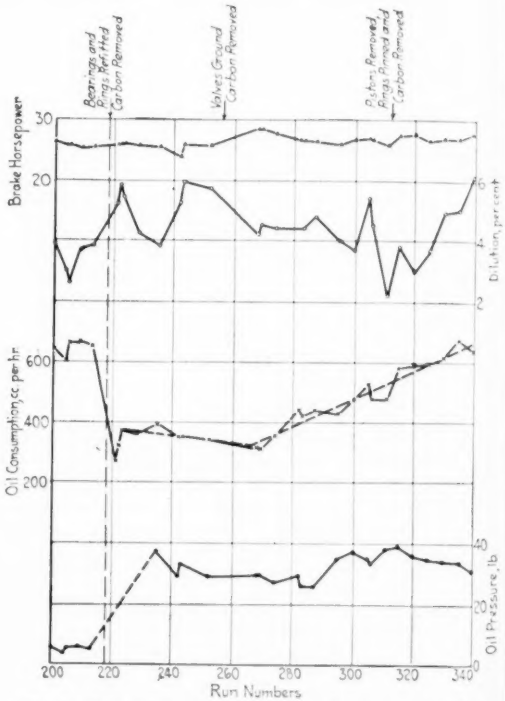

Fig. 5.—Data showing effect of mechanical changes and work done on the engine as the tests progressed. The oil consumption line is of particular interest, especially from Run No. 230 on. It consists of two distinct parts, which are divided by Run No. 267. The first part shows a uniform decrease in oil consumption while the second part shows a uniform increase.

To this engine was coupled a conventional Sprague electric dynamometer, the set up being shown in Figure 3. A Toledo scale was used for reading the torque; a chronometric tachometer for the speed; the fuel was measured volumetrically by suitable glass pipettes; and hot air stoves arranged for control of the carburetor air temperature, there being no hot spot effect on the intake manifold. Mercury thermometers, suitably placed, were used for reading temperatures, the crankcase temperature being read from a thermometer projecting a few inches through the rear hand hole cover in the crankcase.

All the above features are customary, but special attention is called to the details of the lubricating system, some of which are unusual. In the first place, it was considered desirable to know the volume of oil passing through the crank-shaft bearings, which of course controls the volume of oil reaching the cylinder walls.

This was accomplished by closing up the oil pressure-regulating by-pass valve. The oil pump itself then became a meter of the oil passing through the bearings. The oil pressure thus was able to adjust itself to the necessary extent to force the required volume of oil

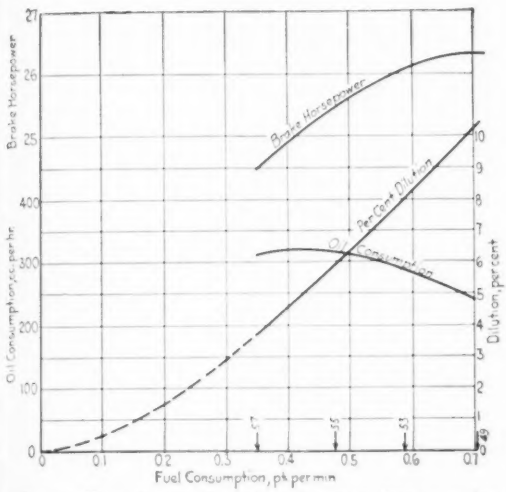

Fig. 6.—Chart showing effect of varying the carburetor setting. It will be seen that the dilution increases almost at the same rate as gasoline consumption. The richer mixtures result in a slightly lower oil consumption. These consumptions are those actually recorded, and were not corrected for their fuel content.

through the bearings. This alteration, though simple in itself, is really far reaching because by such an arrangement a uniform volume of oil is thrown on the cylinder walls at each revolution of the engine, regardless of bearing clearance, and oil temperature or viscosity. The volume of oil flowing through the bearings was brought under control by mounting the oil pump outside the crankcase at the front of the engine where it was driven by change gears.

The second important change comprised the use of the so-called "dry-sump" lubricating system, all the oil being drained from the oil pan into a glass "sump" graduate as shown in Figure 3. The oil pump suction was run from this "sump" graduate, the latter serving as an oil reservoir of very small capacity.

The third change involved the water jacketing of the crankcase in order to control the crankcase temperature. A double-walled sheet metal oil pan was made with steep sloping walls for rapid drainage of oil, water being run through the space between the two walls which are heated or cooled as desired.

TEST ROUTINE

Each routine test consisted of a two hour run during which all the conditions selected for the particular run were held as constant as possible.

In starting up the engine, the cylinder jackets and oil pan were first brought up to the desired temperatures; 400 cc. of oil warmed to 100 deg. F. were then put in the "sump" graduate under the oil pan. A second graduate, of 1000 cc. capacity, was filled with a reserve of warmed fresh oil, and used to maintain the level of the sump graduate at the 400 cc. mark. When the engine was running steadily with all temperatures correct, observation was made of the oil level in the sump graduate every five minutes during the run, a sufficient amount of fresh oil being added as necessary to restore the 400 cc. level. The oil consumption was thus determined by the amount of fresh oil necessary to maintain a constant oil level. Use of such a small volume of oil in the whole lubricating system (hardly one quart) was expected to result in a more rapid dilution; otherwise the results were not affected.

The data secured was plotted for each run, over five minute intervals showing the total oil drawn from the 1000 cc. supply graduate, the oil pressure, the crankcase temperature, and engine torque. (See Figure 4). The actual rate of oil consumption recorded for the run, was taken from the slope of the straight part of the line. At the end of each run, record was made of the oil drained from the crankcase or in other words the amount of oil in circulation. The viscosity was then measured, the percent dilution being estimated from Figure 2.

As is usually the case in work of this nature the first few runs made showed some unexpected irregularities. Occasionally the oil consumption curve would be well developed at a certain slope and then suddenly change to a

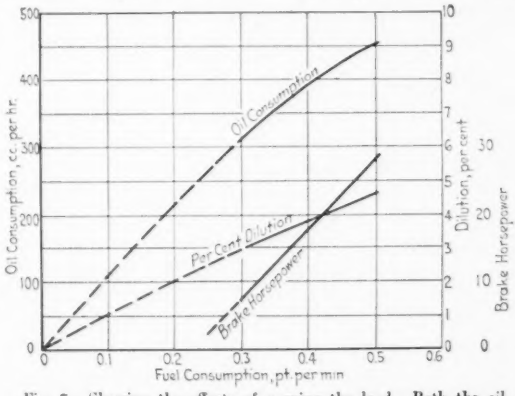

Fig. 7.—Showing the effects of varying the load. Both the oil consumption and dilution are seen to increase as the fuel consumption is increased as a result of opening the throttle.

new slope without any indication of gradual transition. It was surmised that the piston rings might be turning in their grooves until the slots came in line. Consequently, the rings were pinned to insure against this.

In order to record the effects of mechanical changes in the engine as the parts wore during the whole series of these runs, frequent checks or "standard runs" were made under a set of identical conditions. The results are given in Figure 5, together with notes showing mechanical work done on the engine in the meantime.

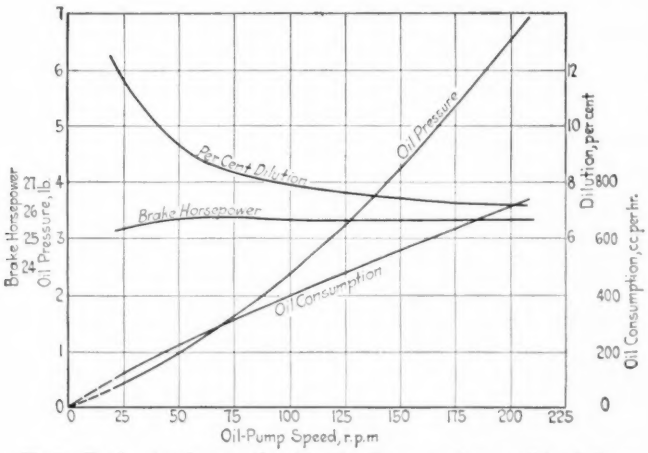

Fig. 8.—By changing the gears that drive the oil pump, various quantities of oil were forced through the crankshaft bearings, with the result shown in this figure. Notice that the oil consumption increases almost in direct proportion with the quantity of oil passing through the bearings. Dilution decreases as the oil consumption increases. The oil pressure rises practically as the square of the volume of oil passing through the bearings

The period from run 221 to 340 (Figure 5) represents about 240 hours' time, or the equivalent of approximately 5,000 miles of passenger car operation. While the dust in the air in the laboratory did not compare with average road dust conditions, yet some wear naturally occurred, with a consequent appreciable tapering of the cylinders. This caused the rings to work in and out a good deal in their grooves. The bearings, however, showed but little wear as indicated by the fact that the oil pressure was well maintained.

Each series of runs was made by alternating each one of the "standard" variables such as the speed, load, spark, mixture, grade of oil, temperatures, etc., at a time, all others being held constant.

The data derived with the oil consumption under complete control, is of interest as it gives rise to the natural inquiry as to what the consumption should be. This is a study outside the scope of the present investigation, though plans are on foot to make a special study of that phase in the near future. For the present, the study includes only the quantity of oil actually consumed,—not how much or little should be consumed. It is to be noted, however, that lowering the oil consumption slightly, raises the brake horsepower delivered until the consumption is less than 200 cc. per hour—which is about 0.015 lbs. per horsepower-hour, and not far from 1000 miles per gallon for a passenger car.

The dilution is seen to decrease as the consumption increases, as would be expected from the greater additions of fresh oil. This seems to explain the difference of oil dilution observed from the truck tests as shown in Figure 1.

The effect of crankcase temperatures upon dilution is another vital point on which valuable data was obtained. When it is considered how cold a crankcase may be in the winter after standing out doors all night, or even in an unheated garage and that normally two or three hours running are required to heat up the engine, it is easy to imagine that crankcase temperatures are normally low enough to be in the region of high dilution. Furthermore, many engineers make a particular point of keeping the crankcase oil temperature as low as possible, by providing large ribbed oil pan areas exposed directly to air blowing under the car. On the other hand data indicates that anything done to keep the crankcase warm should result in less dilution. This is shown in Figure 10 as proof of this contention. The results are given from two seven-hour runs which differed from the regular runs only in their length, and in the fact that the oil viscosity was taken every half hour.

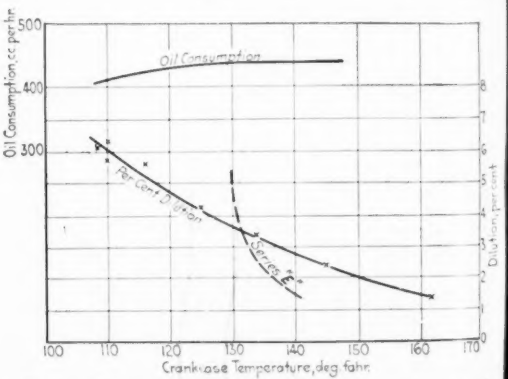

Fig. 9.—Changing of the crankcase temperature, as shown by the above chart, has a greater effect upon dilution than any other variable. Even under the limited range of temperatures possible with this equipment an increase of only 50° Fahr. reduces the dilution by 75%. The shape of the curve indicates that the dilution may increase still more rapidly at lower temperatures.

Another fact which bears out this conclusion is that the very small dilution observed ordinarily on dynamometer runs is undoubtedly due to the high crankcase temperatures involved. During certain of such tests, observed in automobile manufacturers plants, running temperatures have been noted above 200 deg.F.

Carburetor Air Temperature

As a matter of further interest several runs were made with air temperatures of 100 deg. F. at the carburetor instead of the normal 200 deg. F. It was a surprise to discover that there was no increase whatever in the resulting dilution. It does not seem that this can be due to a dry mixture because it has been found that over ⅓ of all the fuel going through the manifold was unvaporized at this temperature.

The Effect of Changing Viscosities

In this series of tests five oils refined from substantially the same crude, but varying in viscosity from 100 to 1300 seconds Saybolt at 100 degrees F. were used successively. The oil consumption varied considerably with the viscosity. The oil pressure, however, did not increase with the viscosity as rapidly as expected, because the high viscosity oils lost a much greater proportion of their viscosity from dilution than the low viscosity oils.

The effect of dilution is shown in Fig. 12 as the ratio of viscosity of the used oil to that of the new oil—indicating a more satisfactory performance for the lower viscosity oils. The greatest power was delivered with an oil which had a viscosity of less than 40" Saybolt at the cylinder temperature—and 60" Saybolt at crankcase temperature.

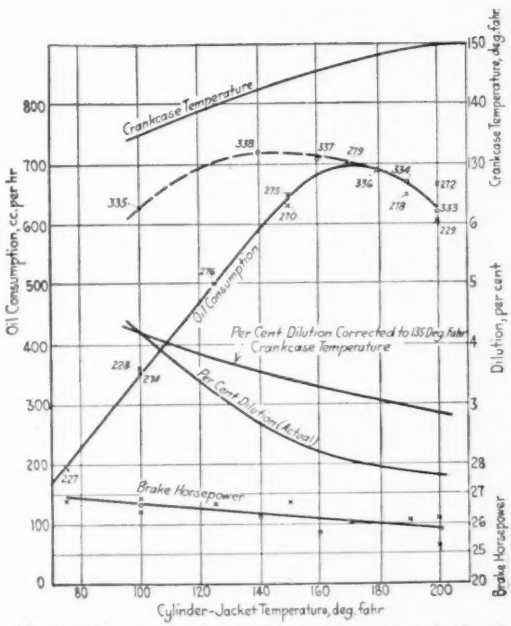

Fig. 11.—The varying of cylinder-jacket temperatures developed data of special interest. As a consequence, these tests were re-run three months later. Run numbers are indicated on the curves. The oil consumption curves developed at these two periods were of very different shape at the lower temperatures, but approached a tangent at the higher temperatures. Note also that in both cases there was a drop in power as the jacket temperature rose. There is evidence that this drop in power was not caused by decreasing volumetric efficiency.

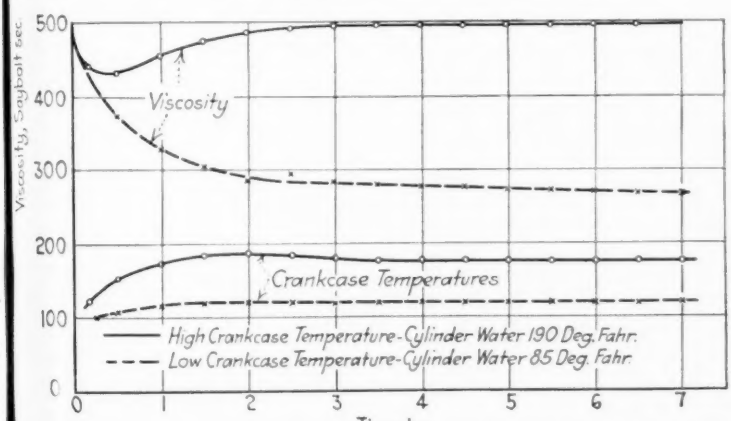

Fig. 10.—The above curves of half-hourly viscosity determinations are almost self-explanatory. The lower viscosity curve was obtained with the lowest cylinder jacket and crankcase temperatures that could be maintained; the upper viscosity curve was taken under the same conditions as the lower, with the exception that the highest cylinder jacket and crankcase temperatures possible were maintained. The drop of viscosity in the early part of the run and its subsequent rise, follows the crankcase temperature and emphasizes the importance of the latter. This data proves that dilution can be practically eliminated without any external devices.

CONCLUSIONS

The data which has been collected during the course of study outlined above in regard to the fundamentals of automobile engine lubrication is of importance in that certain very interesting points have been indicated. For example:

1. *Dilution.*

Crankcase dilution can be reduced to an unimportant factor by keeping the crankcase warm. High jacket water temperature also assists in reducing dilution. Dilution has been shown to be by no means a "breaking down" or decomposition of the oil, since a badly diluted oil can be restored to its original viscosity by evaporation, as is shown by the upper curve of Fig. 10.

2. *Lubricating System*

It is advantageous to change the lubricating system to the extent of eliminating the usual function of the oil by-pass valve as a pressure regulator, instead of using it only as a safety valve. When this is done, the oil pump, serving as a meter of the oil passing through the bearing, must have its capacity reduced to the volume of oil which it is desired to force through the bearings. This system in which all effects of changing bearing clearance, oil viscosity or temperature

are eliminated in their control of the oil supplied to the cylinders, has proved its practicability on the Mercedes and Renault cars, and in airplane engines.

3. *Oil Viscosity Requirements.*

One of the reasons for the marketing of a series of motor oils of different viscosities is to supply a demand for the control of oil consumption to reasonable limits, i.e., if the consumption appears to be too great, an oil of higher viscosity can be used,—if exceptionally low, a lower viscosity oil will not only be satisfactory but probably preferable for other reasons. Indirectly, then, oils of different viscosities are resorted to as a means of compensating for those mechanical differences in engine conditions which control the oil consumption. Almost the same results could be secured by varying the oil pressure.

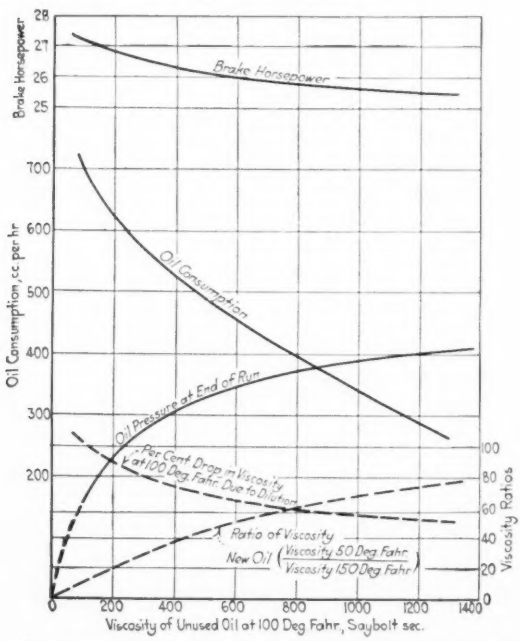
Brake Horsepower
Brake Horsepower
Oil Consumption, cc per hr
Oil Consumption
Oil Pressure at End of Run
Per Cent Drop in Viscosity at 100 Deg Fahr. Due to Dilution
Ratio of Viscosity
New Oil (Viscosity 50 Deg Fahr / Viscosity 150 Deg Fahr)
Viscosity Ratios
Viscosity of Unused Oil at 100 Deg Fahr, Saybolt sec.

Fig. 12.—The effect of using oils of different viscosities is shown in the above chart. The oil consumption varied considerably with the viscosity; the oil pressure, however, did not increase with the viscosity as rapidly as expected, because the heavier oils lost a much greater proportion of their viscosity from dilution than the lighter oils.

4. *Value of Road Tests.*

There are so many factors which influence both oil consumption and dilution, that any tests in which they are not all at least recognized, or preferably held under control, are of very little value. For this reason it is not felt that road tests in which crankcase and cylinder temperatures are unknown are of much analytical value, and even when they are known, some method should be available for converting to a common set of conditions.

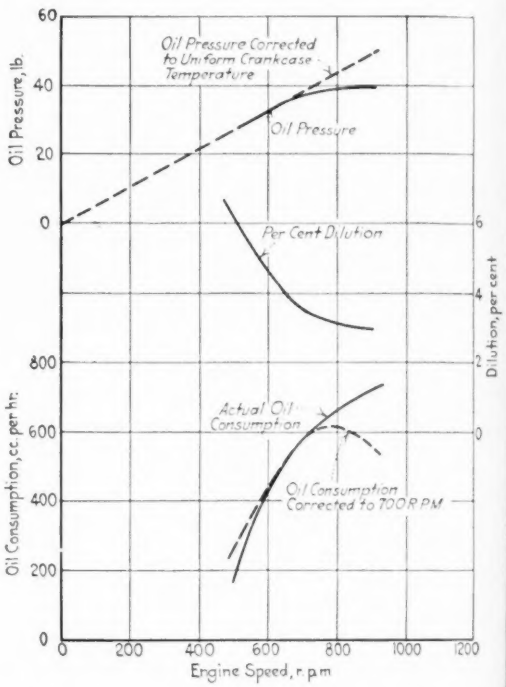
Oil Pressure Corrected to Uniform Crankcase Temperature
Oil Pressure
Oil Pressure, lb.
Per Cent Dilution
Dilution, per cent
Actual Oil Consumption
Oil Consumption Corrected to 700 R P M
Oil Consumption, cc. per hr.
Engine Speed, r.p.m

Fig. 13.—The results of varying the engine speed, as shown above, indicate that as the speed is increased the quantity of oil passing the pistons at each revolution at first increased, and then at higher speeds decreased, even though the volume of oil splashed on the lower part of the cylinder walls was maintained constant per revolution. Oil pressure in this case rose directly with the speed, if correction is made for the different crankcase temperatures. It was impossible in this series of runs to maintain a constant crankcase temperature; therefore the dilution values are not comparable.

5. *Oil Consumption.*

It has been shown that the rate of oil consumption can be completely controlled in an engine, either by the oil viscosity or by adjustment of thermal or mechanical conditions of the engine. How far the oil consumption can be safely reduced is still to be determined, but it is hoped that some light will be thrown on this question, as this experimental work is to be continued. Suggestions as to phases of this study which are of particular interest will be welcomed and will assist in carrying on this work to the ultimately decided benefit of the automobilist.

Printed in U. S. A. by
EDGAR C. RUWE CO., INC.
47 West Street, N. Y. C.